CLAIMS

1. A tilt sensor comprising:

a substrate having piezoresistors formed on its surface and having its entire backside uniformly ground to deflectable thickness; and

a support member for supporting said substrate at one end thereof at least.

2. The tilt sensor according to claim 1, further comprising a weight member arranged in a deformable area of said surface having the piezoresistors formed thereon.

3. The tilt sensor according to claim 1 or 2, characterized in that said piezoresistors are two-dimensionally arranged on the surface of said substrate.

4. The tilt sensor according to claim 3, characterized in that said piezoresistors comprise piezoresistors arranged on the surface of said substrate to detect an amount of deflection of said substrate and piezoresistors arranged on the surface of said substrate to detect an amount of torsion of said substrate.

5. A tilt sensor comprising:

a hexahedral rectangular elastic body having a deformable free surface;

piezoresistors having at least two or more of them provided in a longitudinal direction on a same surface of said hexahedral rectangular elastic body with at least one of them arranged on said free surface;

a support member for supporting said hexahedral rectangular elastic body at both ends thereof in the longitudinal direction; and

a weight member provided approximately at the center in the longitudinal direction of a deformable area of said hexahedral rectangular elastic body.

6. A tilt sensor comprising:

a hexahedral rectangular elastic body having a deformable free surface;

piezoresistors having at least two or more of them provided in a longitudinal direction on a same surface of said hexahedral rectangular elastic body with at least one of them arranged on said free surface;

a support member for supporting said hexahedral rectangular elastic body at one end thereof in the longitudinal direction; and

a weight member provided at the other end in the longitudinal direction of said hexahedral rectangular elastic body.

7. The tilt sensor according to claim 5 or 6, characterized in that at least one of said support member and said weight member is equal to said hexahedral rectangular elastic body in terms of at least one of its length and width.

8. The tilt sensor according to any one of claims 5 to 7, characterized in that said hexahedral rectangular elastic body is a silicon substrate and said piezoresistors are composed of an impurity diffused layer formed on said silicon substrate.

9. The tilt sensor according to claim 8, characterized in that:

said hexahedral rectangular elastic body is a silicon substrate; and

said support member comprises:

a glass substrate having a concave portion formed thereon and composed of a material capable of anodic bonding to said silicon substrate; and

an implant member implanted in said concave portion to prevent anodic bonding to said silicon substrate.

10. The tilt sensor according to any one of claims 5 to 9, comprising the piezoresistors arranged to detect the amount of deflection of said hexahedral rectangular elastic body and the piezoresistors arranged to detect the amount of torsion of said hexahedral rectangular elastic body on the same plane of said hexahedral rectangular elastic body.

11. A method of manufacturing a tilt sensor comprising the steps of:

forming piezoresistors at two or more places on a surface of a wafer;

uniformly grinding an entire backside of said wafer;

bonding a support substrate having a concave portion formed therein to the backside of said wafer so that an area having said piezoresistors formed thereon is inside the concave portion and adjacent to the edge of the concave portion; and

simultaneously cutting said wafer and said support substrate into chips so that a deformable area on a surface

having said piezoresistors formed thereon is supported on both sides of said concave portion.

12. The method of manufacturing a tilt sensor according to claim 11 further comprising the step of:

bonding a weight substrate having a convex portion formed therein to the surface of said wafer so as to arrange said convex portion approximately at the center of said deformable area on the surface having said piezoresistors formed thereon, wherein:

said weight substrate, said wafer and said support substrate are simultaneously cut into chips.

13. A method of manufacturing a tilt sensor comprising the steps of:

forming piezoresistors at two or more places on a surface of a wafer;

uniformly grinding an entire backside of said wafer;

bonding a support substrate having a concave portion formed therein to a backside of said wafer so that an area having said piezoresistors formed thereon is inside the concave portion and adjacent to the edge of the concave portion;

arranging a base approximately at the center of a deformable area on a surface having said piezoresistors formed thereon;

simultaneously cutting the wafer having said base arranged thereon and said support substrate into chips so that the deformable area on the surface having said piezoresistors formed thereon is supported on both sides of said concave portion; and

arranging weight members on said base.

14. A method of manufacturing a tilt sensor comprising the steps of:

forming piezoresistors at two or more places on a surface of a wafer;

uniformly grinding an entire backside of said wafer;

bonding a support substrate having a concave portion formed therein to the backside of said wafer so that one side of said concave portion is positioned adjacent to the edge of an area having said piezoresistors formed thereon and inside said concave portion and another side of said concave portion overlaps with a scribe line of said wafer;

arranging a base in a deformable area on a surface having said piezoresistors formed thereon;

simultaneously cutting the wafer having said base arranged thereon and said support substrate into chips so that the surface having said piezoresistors formed thereon is supported on one side of said concave portion; and

arranging weight members on said base.

15. A method of manufacturing a tilt sensor comprising the steps of:

forming piezoresistors at two or more places on a surface of a wafer;

uniformly grinding an entire backside of said wafer;

bonding a support substrate having a concave portion formed therein to the backside of said wafer so that an area having said piezoresistors formed thereon is inside the concave portion and adjacent to the edge of the concave portion;

bonding a weight substrate having concavity and convexity formed thereon to the surface of said wafer so that the convex portion overlaps with the scribe line at an interval of two chips;

cutting off a portion of a concave portion of said weight substrate in parallel to said scribe line; and

simultaneously cutting said weight substrate, said wafer and said support substrate into chips so that one end of a surface having said piezoresistors formed thereon is supported on one side of the concave portion of said support substrate and the convex portion of said weight substrate is arranged on the surface having said piezoresistors formed thereon.

16. The method of manufacturing a tilt sensor according to any one of claims 11 to 15, characterized in that said grinding is polishing or etching or a combination of them.

17. A tilt sensor comprising:

a deflectable plate having piezoresistors formed on its surface;

a support member for supporting said deflectable plate at one end of said deflectable plate; and

a metallic weight member arranged in a deflectable area of said deflectable plate.

18. A tilt sensor comprising:

an SOI substrate having a silicon layer formed on an insulating layer;

a cavity formed in the insulating layer under said silicon layer;

piezoresistors formed in said silicon layer on said cavity; and

a metallic weight member arranged on said silicon layer on said cavity.

19. The tilt sensor according to claim 17 or 18, characterized in that said deflectable plate or said silicon layer is constricted in an area having said piezoresistors formed therein.

20. A method of manufacturing a tilt sensor comprising steps of:

forming piezoresistors at two or more places in each chip area on a surface of a wafer;

forming a pad in each chip area on the surface of said wafer;

uniformly grinding an entire backside of the wafer having said piezoresistors and pads formed thereon;

bonding a support substrate having a concave portion formed therein to the backside of said wafer so that an area having said piezoresistors formed thereon is positioned adjacent to the edge of said concave portion and said pad is positioned inside the concave portion;

forming a metallic weight member on each pad of said wafer bonded to said support substrate;

forming an opening on said wafer so that the area having said piezoresistors formed therein is constricted; and

cutting the wafer having said opening formed thereon into chips.

21. A method of manufacturing a tilt sensor comprising the steps of:

forming piezoresistors at two or more places in each chip area on a silicon layer formed on a silicon wafer by the intermediary of a silicon dioxide layer;

forming a pad in each chip area on said silicon layer;

forming a metallic weight member on each pad formed on said silicon layer;

forming an opening on said silicon layer so that an area having said piezoresistors formed therein is constricted;

etching a portion of said silicon dioxide layer via the opening formed on said silicon layer and thereby removing the silicon dioxide layer under the area having said piezoresistors formed therein and the area having said metallic weight member formed therein; and

cutting said wafer having the silicon dioxide layer removed therefrom into chips.

22. The method of manufacturing a tilt sensor according to claim 20 or 21, characterized in that said metallic weight member is formed by electroplating.

23. A tilt sensor comprising:

a deflectable plate having piezoresistors formed on its surface;

a support member for supporting said deflectable plate at one end of said deflectable plate; and

a weight member arranged in a deflectable area of said deflectable plate, in which:

said piezoresistors have:

a first piezoresistor group including two pairs of piezoresistors arranged in the positions inside the deflectable area of said deflectable plate and symmetric with respect to a center line going through a middle point of width of said deflectable plate; and

a second piezoresistor group including two pairs of piezoresistors arranged in the positions inside the deflectable area of said deflectable plate, symmetric with respect to said center line and different from the positions of the piezoresistors in said first piezoresistor group, and constitute a first full bridge circuit with said first piezoresistor group and a second full bridge circuit with said second piezoresistor group, and further comprising:

a first tilt angle calculating means for calculating a tilt angle around the axis along the longitudinal direction of said deflectable plate based on the output of said first full bridge circuit; and

a second tilt angle calculating means for calculating a tilt angle around the axis along the lateral direction of said deflectable plate based on the output of said second full bridge circuit and the tilt angle calculated by said first tilt angle calculating means.

24. A tilt sensor comprising:

a deflectable plate having piezoresistors formed on its surface;

a support member for supporting said deflectable plate at one end of said deflectable plate; and

a weight member arranged in a deflectable area of said deflectable plate, in which:

said piezoresistors have:

a first piezoresistor group including two pairs of piezoresistors arranged in the positions inside the deflectable area of said deflectable plate and symmetric with respect to a center line going through a middle point of width of said deflectable plate; and

a second piezoresistor group including a plurality of piezoresistors arranged in the positions inside the deflectable area of said deflectable plate and on said center line, and

constitute a first full bridge circuit with said first piezoresistor group and a second half bridge circuit with said second piezoresistor group, and further comprising:

a first tilt angle calculating means for calculating a tilt angle around the axis along the longitudinal direction of said deflectable plate based on the output of said first full bridge circuit; and

a second tilt angle calculating means for calculating a tilt angle around the axis along the lateral direction of said deflectable plate based on the output of said second half bridge circuit and the tilt angle calculated by said first tilt angle calculating means.

25. A tilt sensor comprising:

a deflectable plate having piezoresistors formed on its surface;

a support member for supporting said deflectable plate at one end of said deflectable plate; and

a weight member arranged in a deflectable area of said deflectable plate, in which:

said piezoresistors have a first piezoresistor group including two pairs of piezoresistors arranged in the positions inside the deflectable area of said deflectable plate and symmetric with respect to a center line going through a middle point of width of said deflectable plate, and

constitute a first full bridge circuit with said first piezoresistor group and a second full bridge circuit with said first piezoresistor group and different connection from said first full bridge circuit, and further comprising:

a first tilt angle calculating means for calculating a tilt angle around the axis along the a longitudinal direction of said deflectable plate based on the output of said first full bridge circuit; and

a second tilt angle calculating means for calculating a tilt angle around the axis along the lateral direction of said deflectable plate based on the output of said second full bridge circuit and the tilt angle calculated by said first tilt angle calculating means.

26. A method of measuring a tilt angle using a tilt sensor comprising:

a deflectable plate having piezoresistors formed on its surface;

a support member for supporting said deflectable plate at one end of said deflectable plate; and

a weight member arranged in a deflectable area of said deflectable plate, in which:

said piezoresistors have:

a first piezoresistor group including two pairs of piezoresistors arranged in the positions inside the deflectable area of said deflectable plate and symmetric with respect to a center line going through a middle point of width of said deflectable plate; and

a second piezoresistor group including two pairs of piezoresistors arranged in the positions inside the deflectable area of said deflectable plate, symmetric with respect to said center line and different from the positions of the piezoresistors in said first piezoresistor group, and the method including:

a first bridge circuit output step of constituting a first full bridge circuit with said first piezoresistor group and outputting therefrom;

a second bridge circuit output step of constituting a second full bridge circuit with said second piezoresistor group and outputting therefrom,

a first tilt angle calculating step of calculating a tilt angle around the axis along the longitudinal direction of said deflectable plate based on the output of said first full bridge circuit; and

a second tilt angle calculating step of calculating a tilt angle around the axis along the lateral direction of said deflectable plate based on the output of said second full bridge

circuit and the tilt angle calculated in said first tilt angle calculating step.

27. A method of measuring a tilt angle using a tilt sensor comprising:

a deflectable plate having piezoresistors formed on its surface;

a support member for supporting said deflectable plate at one end of said deflectable plate; and

a weight member arranged in a deflectable area of said deflectable plate, in which:

said piezoresistors have:

a first piezoresistor group including two pairs of piezoresistors arranged in the positions inside the deflectable area of said deflectable plate and symmetric with respect to a center line going through a middle point of width of said deflectable plate; and

a second piezoresistor group including a plurality of piezoresistors arranged in the positions inside the deflectable area of said deflectable plate and on said center line, and the method including:

a first bridge circuit output step of constituting a first full bridge circuit with said first piezoresistor group and outputting therefrom; and

a second bridge circuit output step of constituting a second half bridge circuit with said second piezoresistor group and outputting therefrom;

a first tilt angle calculating step of calculating a tilt angle around the axis along the longitudinal direction of said

deflectable plate based on the output of said first full bridge circuit; and

a second tilt angle calculating step of calculating a tilt angle around the axis along the lateral direction of said deflectable plate based on the output of said second half bridge circuit and the tilt angle calculated in said first tilt angle calculating step.

28. A method of measuring a tilt angle using a tilt sensor comprising:

a deflectable plate having piezoresistors formed on its surface;

a support member for supporting said deflectable plate at one end of said deflectable plate; and

a weight member arranged in a deflectable area of said deflectable plate, in which:

said piezoresistors have a first piezoresistors group including two pairs of piezoresistors arranged in the positions inside the deflectable area of said deflectable plate and symmetric with respect to a center line going through a middle point of width of said deflectable plate, and the method including:

a first bridge circuit output step of constituting a first full bridge circuit with said first piezoresistor group and outputting therefrom; and

a second bridge circuit output step of constituting a second full bridge circuit with said first piezoresistor group and different connection from said first full bridge circuit and outputting therefrom;

a first tilt angle calculating step of calculating a tilt angle around the axis along the longitudinal direction of said deflectable plate based on the output of said first full bridge circuit; and

a second tilt angle calculating step of calculating a tilt angle around the axis along the lateral direction of said deflectable plate based on the output of said second full bridge circuit and the tilt angle calculated in said first tilt angle calculating step.

29. An azimuth sensor for detecting an azimuth, characterized by comprising:

the tilt sensor according to claims 1 to 10, claims 17 to 19 or claims 23 to 25; earth magnetism detecting means, at least biaxial, for detecting geomagnetic components in orthogonal directions; and

azimuth calculating means for calculating an azimuth based on tilt angle data obtained by the tilt sensor and geomagnetic data obtained by the earth magnetism detecting means.

30. A cellular phone comprising the azimuth sensor according to claim 29 built therein.